ATTACHMENT 1

PROGRESS REPORT
~~TECHNICAL REPORT~~

Report on a Study of Methods to Determine the Effects of Large Surface Effect Vehicles on Arctic Tundra

November 1971

Prepared by
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CONTRACTOR	Arctic Institute of North America
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PROGRAM MANAGER	Robert C. Faylor

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INTRODUCTION

Under the modification number 01 of the above stated contract, additional research on the polar effect on design of surface effect vehicles was performed. To accomplish this and in order to establish the design criteria for large surface effect vehicles, the Institute proceeded to formulate a test program which would provide a method of measuring and evaluating the consequences of operating a surface effect vehicle using varying cushion lift pressures over arctic tundra areas in various operating modes including parking, hovering and during flight of single and multiple passes.

Robert C. Faylor and Ralph A. Lenton of the staff of the Arctic Institute were assigned to this task.

STATE OF THE ART INVESTIGATION

Consultations with several ecologists, biologists and botanists regarding tundra conditions were held in an effort to determine standards for tundra definition and measurements.

The First International Arctic Aviation Conference in Fairbanks, Alaska and the Fifth Canadian Symposium on Air Cushion Technology in Ottawa, Canada were attended by Faylor and Lenton respectively.

Consultations with representatives of industry and manufacturers to identify suitable design materials in order to define and formulste air flow and apparatus requirements to make a vehicle capable of simulating the projected pressures and velocities associated with large surface effect vehicles.

TEST METHOD DESIGN AND ANALYSIS

With the assistance of Mr. J. Petit, a preliminary design study of one method of a simulation device was prepared. This vehicle simulator presents a simple and inexpensive manner for gathering important data.

A Surface Effect Vehicle Simulator size of 4 ft. x 6 ft. was selected to obtain a representative path or air contact pressure area. The vehicle air flow characteristics were selected to obtain cushion pressures up to 250 lbs/ft.^{2}

The simulation vehicle will be mounted on a tracked vehicle and towed across the tundra. The tracked vehicle simulator arrangement will permit test of potential tundra damage with the simulation SEV in "lift off", forward speed, set down and multiple passes, and other arrangements that approximate expected field conditions. (see figure 1)

Air flow analysis for two general types of vehicles were made. The first is the so-called simple plenum chamber craft. The second vehicle is a peripheral jet craft.

Instrumentation and construction are also discussed.

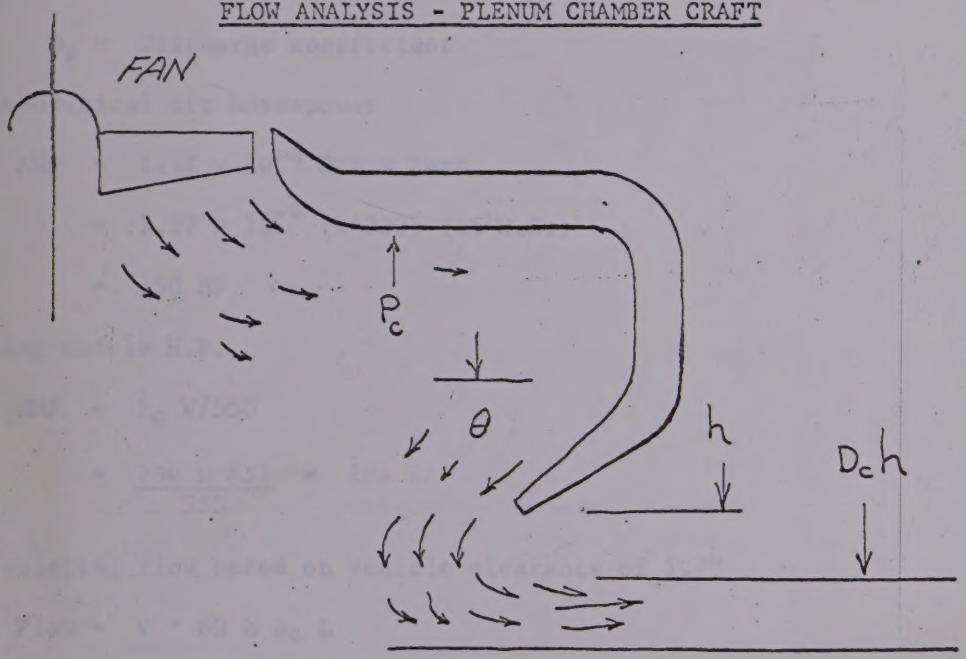
The proposed test craft was designed with sufficient flexibility to permit evaluation of plenum chamber and peripheral jet craft. The vehicle also was designed to permit various skirt and hood arrangements to be used. The design shown (Figure 3) employs variable area escape jet nozzles. This area adjustment permits additional control of exit velocity, flow and plenum pressure.

THE PLENUM CRAFT

The plenum chamber craft relies upon the back pressure developed within the plenum as a result of the restricted air flow between the craft and ground to obtain lift. The lift is the product of the pressure in the plenum and surface area.

The flow analysis for this craft is presented.

FLOW ANALYSIS - PLENUM CHAMBER CRAFT



From Bernoulli's Equation

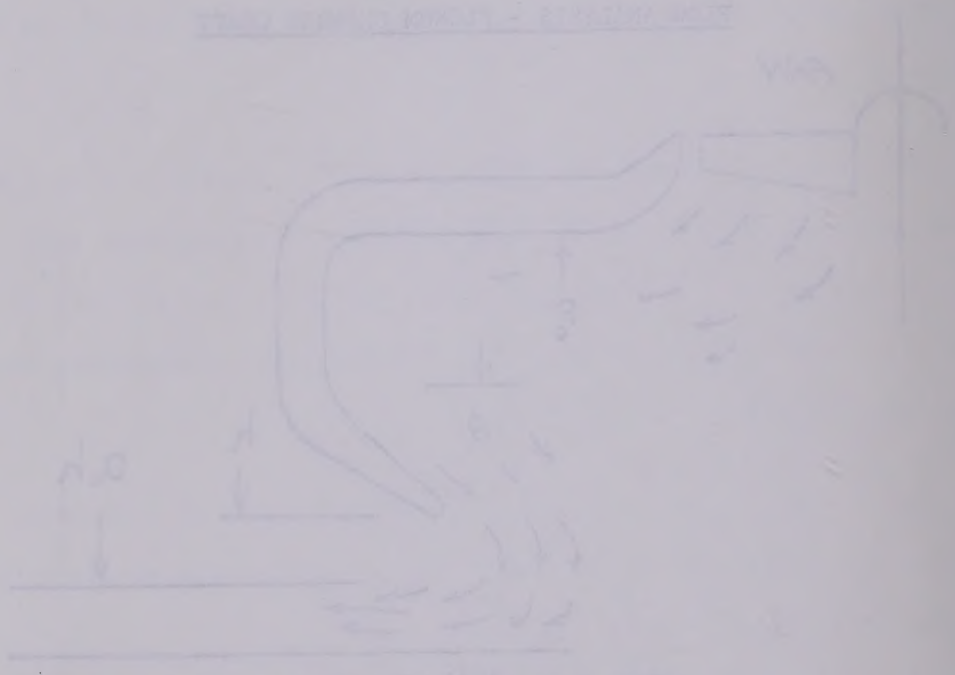
(Assuming Low Velocity Within the Plenum)

$$V = \sqrt{\frac{2g}{\gamma} P_c}$$

where P_c = 250 lbs/ft^2 in problem statement. By substitution

$$V = \sqrt{\frac{64.4}{.079}} (250) \quad \text{using air temp. } 40^\circ F$$

$$V = 451 \text{ ft./sec.}$$



The volume air flow can be determined from the velocity and vehicle clearance.

$$\text{Vol. Air Flow} = V \cdot 60\ h\ D_c\ L$$

$$= 451 \text{ ft./sec. } (60)\ (\tfrac{1}{12})\ (.537)\ (20)$$

$$= 24{,}300 \text{ CFM}$$

where V = Velocity

h = Clearance

L = Perimeter

D_c = Discharge coefficient

The theoretical air horsepower

$$AHP = 1.57 \times 10^{-4} \text{ CFM x Head}$$

$$= 1.57 \times 10^{-4}\ (24300)\ (48\text{"W.G.})$$

$$= 190 \text{ HP}$$

checking nozzle H.P.

$$NHP = P_c\ V/550$$

$$= \frac{250 \times 451}{550} = 204 \text{ HP}$$

Recalculating flow based on vehicle clearance of 1.7"

$$\text{Vol. Flow} = V \cdot 60\ h\ D_c\ L$$

$$= (451)\ (60)\ (\tfrac{1.7}{12})\ (.537)\ (20)$$

$$= 41{,}000 \text{ CFM}$$

$$AHP = 1.57 \times 10^{-4} \text{ CFM x Head}$$

$$= 1.57 \times 10^{-4}\ (41000)\ (48\text{"W.G.})$$

The lifting ability based on plenum pressure of 250 lbs/ft.^{2}

$$W = PA$$

$$= 250 \times 4 \times 6$$

$$= 6000 \text{ lbs.}$$

A summary of plenum craft flow data is presented in the table below.

Height Inches	Weight Lifting Lbs.	Flow CFM	Pressure Static lbs/ft^2	AHP Theoretical
1	6,000	24,300	250	185
1.7	6,000	41,000	250	310
3	6,000	73,000	250	560

THE PERIPHERAL JET CRAFT

The peripheral jet craft relies upon the action of a high velocity directed air jet escaping through the peripheral of the vehicle to maintain a cushion pressure under the craft.

Typically this craft employs less volume at higher pressures and, subsequently, less power than the plenum chamber craft.

The peripheral jet craft employs nozzles in the perimeter of the craft. These nozzles and assembly take on the appearance of a skirt; hence they are referred to as the skirt of the craft. A great deal of attention is given to skirt design and its ability to survive repeated vehicle "set down", "lift off", and vibration as well as the nozzle junctions. For the simulation application, the most important consideration is to develop the maximum cushion pressures and velocities with a minimum power requirement. For this requirement, the skirt was designed as in Figure 3. This design permits nozzle area adjustments and flexibility in replacing and altering the design for other tests.

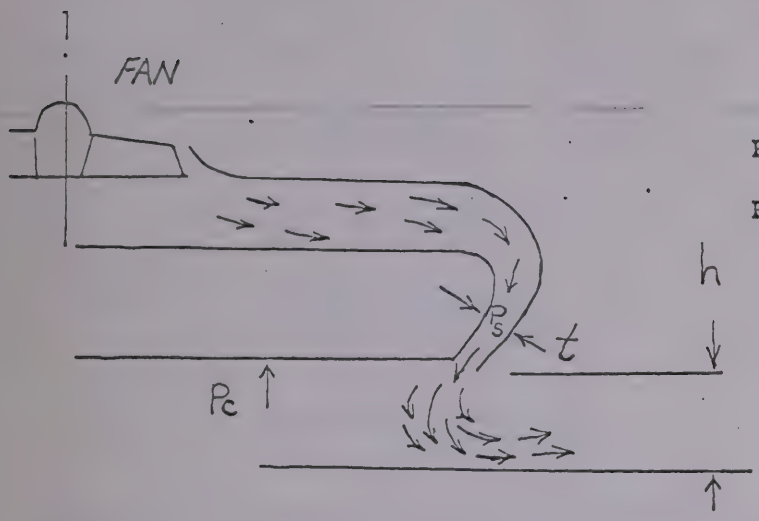
The top of the craft where the air is ducted to the nozzle is called the hood. The hood is designed to support the skirt, instrumentation, and duct the supply air to the skirt area. The hood will be used to attach the simulation vehicle to the tractor arm.

Changes in the hood and skirt design to expand the test capabilities are readily accomplished since the engine and fan are mounted on a beam away from the simulation vehicle. (See Figure 2)

The air flow requirement, air horsepower, vehicle height and lifting capabilities are calculated in the following pages. A table of results is found below.

Cushion P_c lbs/ft^2	Velocity ft./sec.	Flow CFM	AHP	Height Inches	Lift lbs.
250	316	31,600	238	1.7	6,000

PERIPHERAL JET CRAFT - AIRFLOW ANALYSIS



P_c = Cushion pressure

P_s = Nozzle static pressure

From Horizontal Change in Momentum

(1) $P_c h = J_J \cos\theta + J_c$ $\qquad J_J = \overline{mv}$

Hovercraft design data suggests

$$P_s = \frac{1}{2} P_c$$

and total pressure H_j and P_s are constant across t.

(2) $V = \sqrt{\frac{2g}{\gamma}\left(H_j - \frac{P_c}{2}\right)}$, where velocity head equals (Total - Static)

We may substitute V in equation (1) by replacing J:

$$J = \frac{\gamma}{g} V_j^2 t$$

(3) $P_c h = \frac{\gamma}{g} V_j^2 t\,(1 + \cos\theta)$, where $J_J = J_C$ no friction.

It is very important to note we cannot employ equation (3) without the limits of equation (2). We may proceed to obtain design information from equation (2) and (3). Considering the case of maximum utilization

Solve for $V = \sqrt{\frac{2g}{\gamma}(H_c - \frac{P_c}{2})}$

where $P_c = 250$ and $P_c \approx H_c$

$$V = \sqrt{\frac{64.4}{.079}\ (250 - 125)}$$

$$V = 316 \text{ ft/sec} \quad (215 \text{ MPH})$$

By setting the nozzle width, t = 1", we can solve the height and volume flow.

From equation (3)

$$P_c h = \frac{\gamma}{g} V^2 t\ (1 + \cos\theta) \qquad \theta = 45^\circ \text{ arb.}$$

$$t = 1" \text{ arb.}$$

$$P_h = \frac{.079 \times 10.2 \times 10^4}{32.2}\ (1.707)$$

$$= 35.8$$

$$h = 35.8/250 = .14' = 1.7"$$

The volume flow

$$\text{Vol. flow} = V\ (60)\ (t)\ (L)$$

$$= (316)\ (60)\ (\tfrac{1}{12})\ (20)$$

$$= 31{,}000 \text{ CFM}$$

The theoritical air horsepower

$$\text{AHP} = 1.57 \times 10^{-4} \text{ CFM x Head}$$

$$= 1.57 \times 10^{-4}\ (31{,}600)\ (48"\text{W.G.})$$

$$= 238 \text{ HP}$$

SIMULATION VEHICLE CONSTRUCTION AND CONTROL

The simulation vehicle will employ a large industrial centrifugal fan and automotive V-8 engine to achieve the air flow and pressures required. The fan and engine will be mounted together clear from the simulation vehicle. (This arrangement is shown in Figure 3.)

The minimum fan requirements are approximately 35,000 CFM at a total head in excess of 48" H_2O W.G. The V-8 engine will have to develop horsepower in the neighborhood of 300 BHP.

A fan suitable for this application, modified to insure proper strength, and operating at 2800 R.P.M. is the Buffalo forge size 60 AW industrial exhauster. From the rated fan data at 1482 R.P.M., the performance at 2800 R.P.M. is calculated.

$$CFM = CFM_1 \left[\frac{n_2}{n_1}\right]$$

$$= 19800 \left[\frac{2800}{1482}\right]$$

$$= 37400$$

$$P = P_1 \left[\frac{n_2}{n_1}\right]^2$$

$$= 20 \left[\frac{2800}{1482}\right]^2$$

$$= 71" \text{ W.G. Static}$$

This fan is more than adequate and should provide good performance. The extra pressure developed will be useful in meeting pressure drops in the transfer duct between fan and hood as well as other losses.

AIR FLOW CONTROL

The air flow to hoods and skirt can be adjusted by changing the fan engine R.P.M. or by regulating the air flow in the feed duct (e.g., letting some air escape through an orifice or blocking some of the air flow with a baffle).

POSITION AND HEIGHT CONTROL

The tracked vehicle is equipped with an adjustable arm which can be hydraulically positioned. Mounted on this arm is the engine fan combination as well as the simulator vehicle. The simulator vehicle is easily positioned by this movable arm. Provisions are provided for stacking weight on the simulation vehicle hood. These weights will be necessary to limit the vehicle clearance under operation and to provide maximum cushion pressures and velocities.

INSTRUMENTATION

Two major craft air parameters of importance to evaluating tundra damage are: the craft cushion pressure and nozzle escape velocity.

Both static pressure and velocity pressure are easily and conveniently measured with standard pitot tubes located within the craft, as shown in Figure 2. The pitot tubes are piped to pressure gages on the instrument panel. The velocity tube may be read directly or the pressure reading converted to velocity.

Craft forward speed is easily measured by the usual 5th wheel speedometer.

COST ESTIMATE - SIMULATION VEHICLE ONLY

Item	Engr. Hrs.	Des./Draft Hrs.	Liaison Hrs.	Supv. Hrs.
Hood	100	200		
Skirt	150	300		
Components	100	150		
Fan	50	60		
Ducting	25	40		
Motor	50	60		
Integration	45	80		
Direct Labor Hours	520	890	40	100
Costs	$3900	$5340	$300	$1000

Direct Labor Totals	3,900
	5,340
	300
	1,000
	$10,540

Material Charge (Components)

Engine	$1,500
Fan	3,500
Duct	500
Transmission	1,000
	$6,500

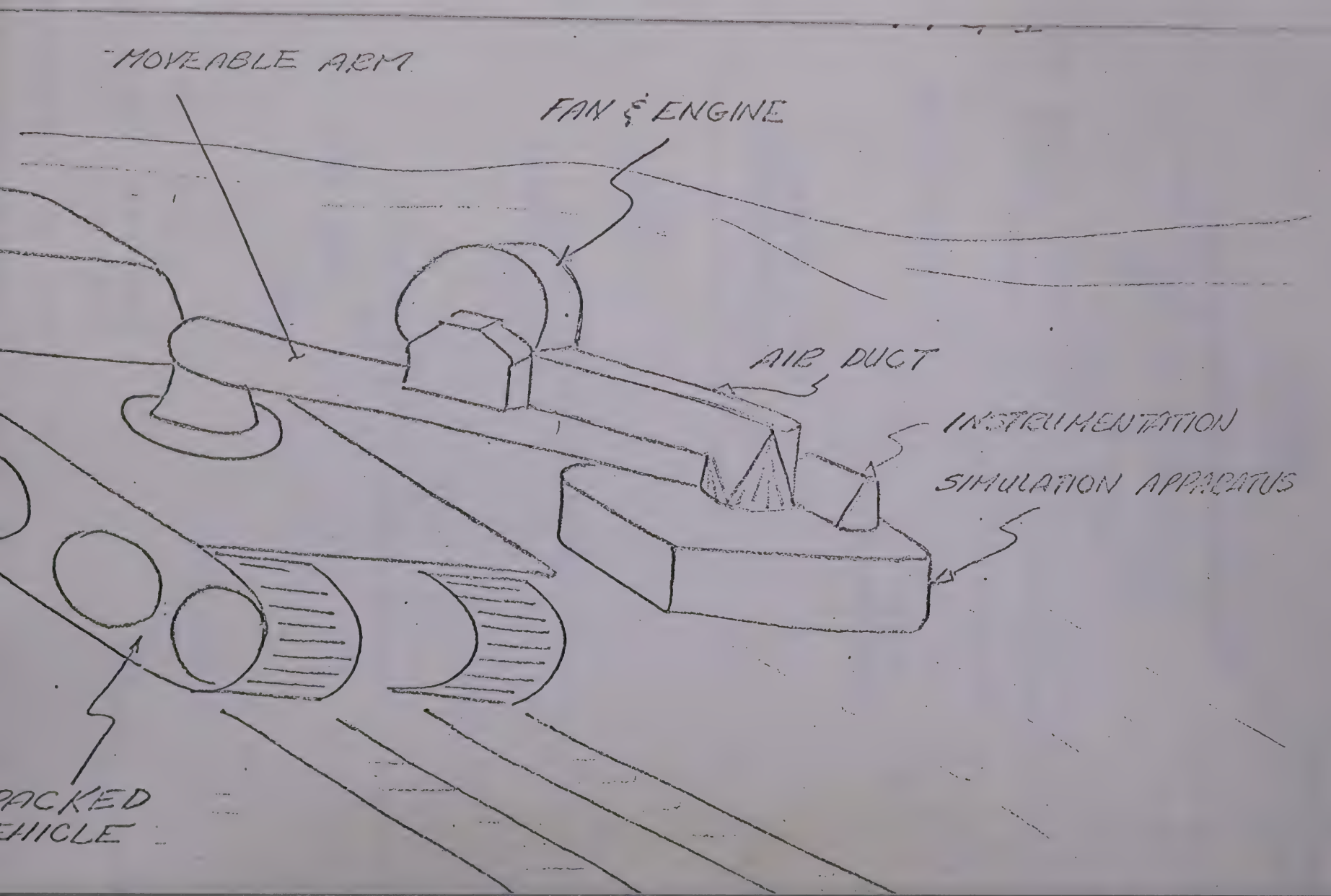
Shop Charge (Fabrication)

Hood	$2,000
Skirt	2,000
Components	3,000
Mtl. Mtgs.	2,000
	$9,000

TOTALS:

Direct Labor	$10,540
Material	6,500
Fabrication	9,000
Total	$26,040

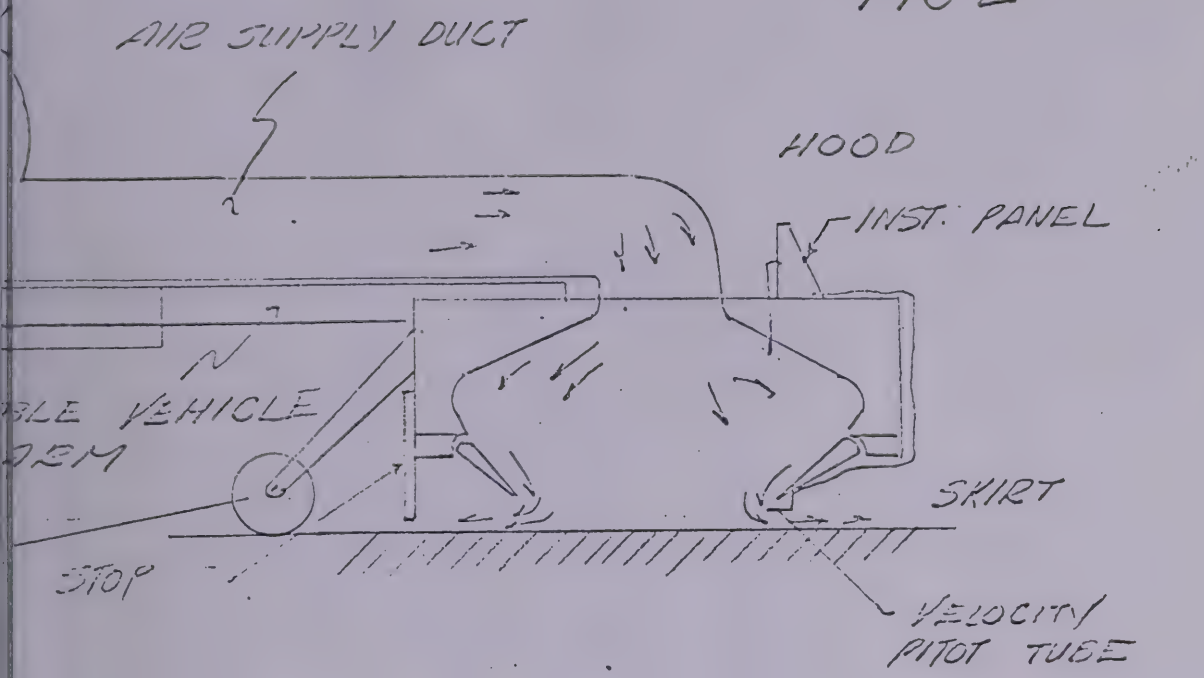
The above costs do not include the tracked vehicle and hydracrane arm.


MOVEABLE ARM
FAN & ENGINE
AIR DUCT
INSTRUMENTATION
SIMULATION APPARATUS
PACKED
EHICLE

NGINE COMBINE

PLENUM CHAMBER CRAFT

FIG 2



PERIPHERAL JET CRAFT

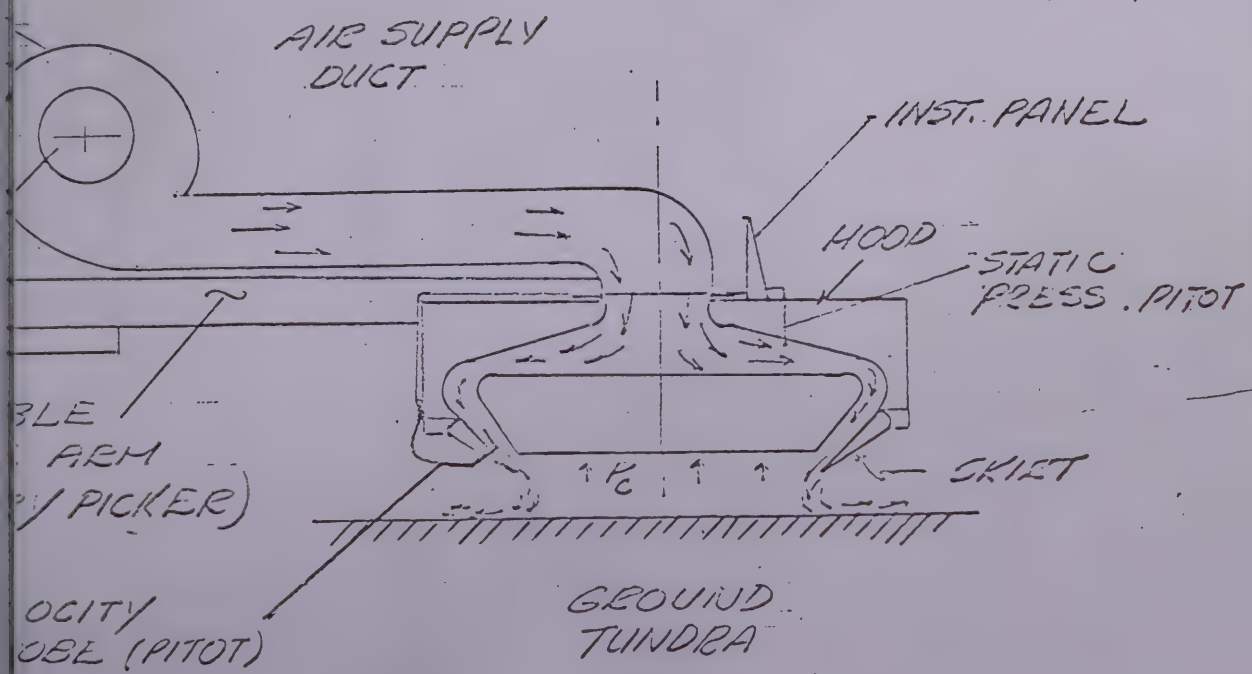
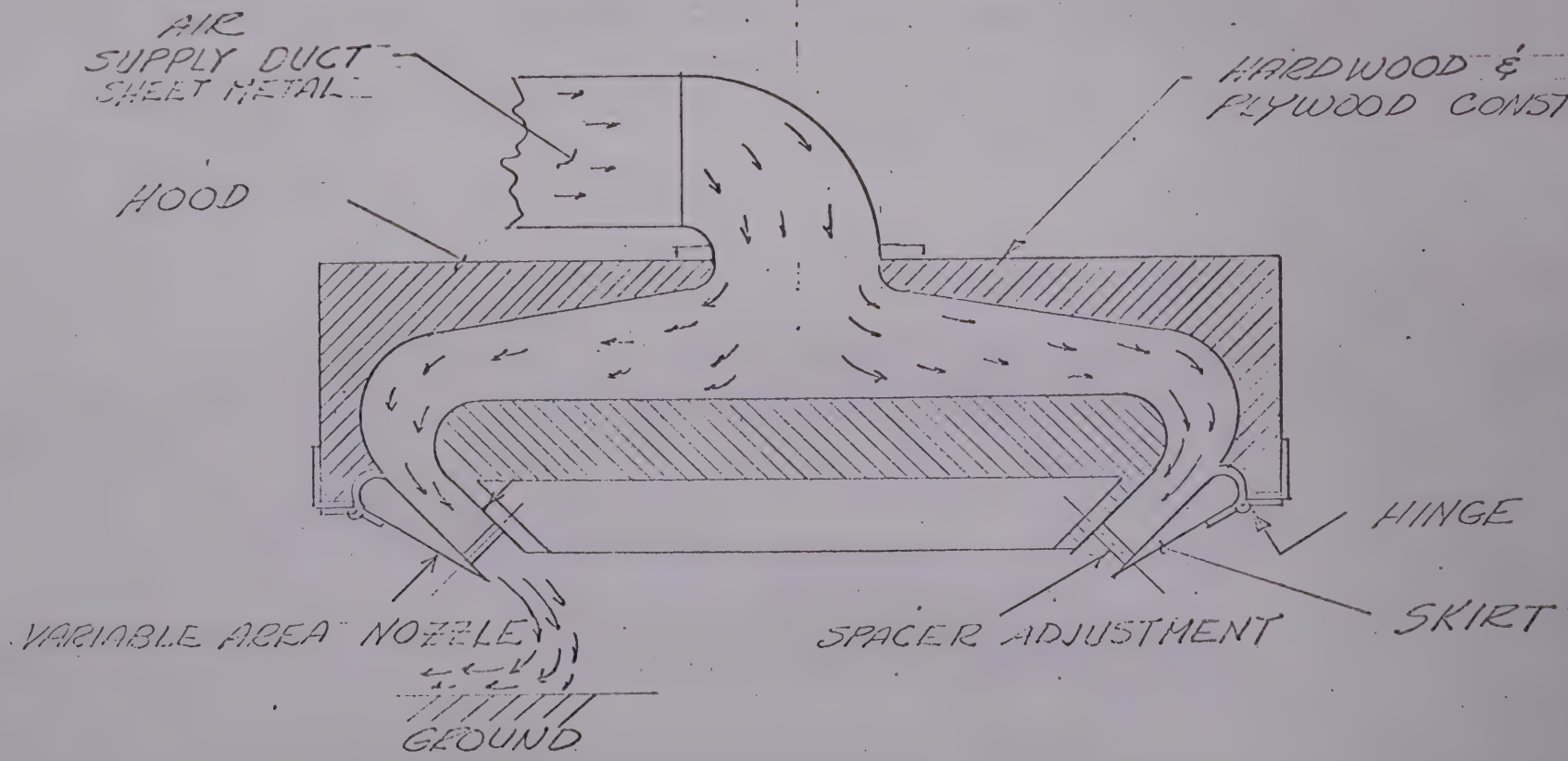


FIG 2



CONSTRUCTION SCHEME

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